Libby Asbestos Site, Operable Unit 3
Remedial Investigation/Feasibility Study
Project Status Meeting

June 24, 2008
11:00 AM – 5:00 PM

Proposed Agenda

1. **Project Schedule** **11:00 AM**

    a. Remedial Investigation (RI) field work (we'll review schedule for field work, data analysis, data verification/validation, field sampling summary report)
        i. Phase I
        ii. Phase IIA (surface water and sediment), IIB (air and groundwater), Phase IIC (ecological data)
        iii. Phase III
    b. RI Report (we'll develop a schedule based on the AOC requirements)
    c. Baseline Risk Assessment
    d. Feasibility Study (FS)

2. **Discussion of OU3 Study Area Boundary** **NOON**

-BREAK-

3. **Preliminary Discussion of Phase III RI (activity based sampling)** **1:30 PM**

    a. Report from Remedium on their site visit to Plum Creek logging operation
    b. Availability of personal air monitoring data from OU3 RI work
    c. Preliminary discussion of scenarios to be characterized in Phase III RI
    d. Pilot study in 2008?

-BREAK-

4. **Preliminary Discussion of FS** **3:00 PM**
    a. Preliminary draft remedial action objectives
    b. Conceptual approaches to remediation
    c. Availability of complete mine reclamation documents from W.R. Grace

-BREAK-

5. **Update on Project Costs (Project Managers Only)** **4:00 PM**

Libby Asbestos Site, Operable Unit 3
Schedule Review – June 24, 2008

	START	END	NOTES
RI FIELD WORK			
Phase I field work	September 2007	October 2007	
Phase I Field Summary Report		December 2007	
Phase I analytical data	October 2007	June 2008	Additional duff samples expected Additional lab QC samples expected (LA)
Phase IIA field work	April 2008	October 2008	Surface water and sediment
Phase IIB field work	July 2008	October 2008	Air and groundwater (need SAP)
Phase IIC field work	August 2008	October 2008	Ecological data
Phase II Field Summary Report		December 15, 2008	
Phase II analytical data	April 2008	Early January 2009	
Phase III field work	April 2009	October 2009	Activity based sampling, data to support RI/FS
Phase III Field Summary Report		December 15, 2009	
Phase III analytical data	April 2009	Early January 2010	

	START	END	NOTES
RI REPORT			
Draft RI Report submittal		End of January 2010	Administrative order requirement
EPA/MDEQ comments		Early March 2010	
Final RI Report submittal		Mid-April 2010	Administrative order requirement
SLERA	MAY	~~[illegible]~~ 2010	
Draft HHRA		Early-March 2010	
Final HHRA		Mid-December 2010	
FS			
Final RAOs		Mid-December 2010	
Draft Development and Screening of Alternatives		Mid-February 2011	Administrative order requirement
EPA/MDEQ comments		Early ~~May~~ April 2011	
Final Development and Screening of Alternatives		Early May 2011	Administrative order requirement
Draft FS Report		Early July 2011	Administrative order requirement
EPA/MDEQ comments		Mid-August 2011	
Final FS Report		Mid-September 2011	Administrative order requirement

LIBBY OU3 PHASE II
ESTIMATED COSTS FOR 2008

Line No.	Phase	EMSL	ENERGY LABS	PARA-METRIX	MWH	MIKE CHAPMAN	TOTALS
1	ELEMENT 1: SEASONAL SURFACE WATER AND SEDIMENT MONITORING	$ 17,130	$ 141,160	-	$ 197,097	$ 5,000	$ 360,387
2	ELEMENT 2: SPRING RUNOFF MONITORING	$ 33,495	-	-	$ 183,762	$ 30,000	$ 247,257
3	ELEMENT 2 SUPPLEMENTARY: WATER AND SEDIMENT SAMPLING ROUNDS	$ 12,180	-	-	$ 151,941	(c)	$ 164,121
4	ELEMENT 2 : EQUIPMENT AND IMPLEMENTATION	-	-	-	(a)	(c)	$ -
5	ELEMENT 3: SUMMER AND FALL MONITORING	$ 3,312	-	-	$ 110,561	$ 5,000	$ 118,873
6	ELEMENT 4: CONTINUOUS PRECIPITATION AND FLOW MONITORING	-	-	-	$ 116,114	$ 7,000	$ 123,114
7	ELEMENT 5: COLLECTION OF WATER FOR TOXICITY TESTING	-	-	-	(b)	-	$ -
8	KOOTENAI RIVER MONITORING	$ 4,272	$ 6,500	-	(b)	$ 8,000	$ 18,772
9	WELL WATER REHABILITATION AND SAMPLING	$ 3,105	-	-	$ 118,131	$ 2,000	$ 123,236
10	PRELIMINARY EVALUATION OF REMEDIAL ALTERNATIVES AND GENERAL ENVIRONMENTAL SERVICES	-	-	-	$ 58,029	-	$ 58,029
11	AMBIENT AIR MONITORING	$ 21,888	-	-	$ 118,831	$ 2,000	$ 142,719
12	FISH TOXICITY TESTING	$ 7,245	-	$ 54,969	-	-	$ 62,214
13	TOTALS	$ 102,627	$ 147,660	$ 54,969	$ 1,054,466	$ 59,000	$ 1,418,722

(a) This cost is included in MWH Cost Estimates in Line 3.
(b) These costs are included in MWH Cost Estimates in Line 5.
(c) Included in May invoice.

6/19/2008

ELEMENT 1 SAMPLING
SEASONAL SURFACE WATER AND SEDIMENT MONITORING

Location	WATER EMSL	WATER Energy Labs	SEDIMENT EMSL	SEDIMENT Energy Labs	SUB-TOTAL	Times Collected	TOTAL
URC-1	$ 207	$ 1,125	$ 42	$ 500	$ 1,874		
URC-1A	$ 207	$ 1,125	$ 42	$ 500	$ 1,874		
URC-2	$ 207	$ 1,125	$ 42	$ 500	$ 1,874		
LRC-1	$ 207	$ 1,125	$ 42	$ 845	$ 2,219		
LRC-2	$ 207	$ 2,520	$ 42	$ 1,970	$ 4,739		
LRC-3	$ 207	$ 1,125	$ 42	$ 845	$ 2,219		
LRC-4	$ 207	$ 1,125	$ 42	$ 845	$ 2,219		
LRC-5	$ 207	$ 1,125	$ 42	$ 845	$ 2,219		
LRC-6	$ 207	$ 1,125	$ 42	$ 845	$ 2,219		
FC-1	$ 207	$ 1,125	$ 42	$ 500	$ 1,874		
FC-2	$ 207	$ 1,125	$ 42	$ 500	$ 1,874		
FC-Pond	$ 207	$ 1,125	$ 42	$ 500	$ 1,874		
FC Pond Sed Grabs (5)	-	-	$ 210	$ 2,500	$ 2,710		
TP	$ 207	$ 1,125	$ 42	$ 500	$ 1,874		
TP Sed Grabs (17)	-	-	$ 714	$ 8,500	$ 9,214		
UTP-Depth 1	$ 207	$ 1,125	$ 42	$ 500	$ 1,874		
UTP-Depth 2	$ 207	$ 1,125	$ 42	$ 500	$ 1,874		
TP-TOE1	$ 207	$ 2,520	$ 42	$ 500	$ 3,269		
TP-TOE2	$ 207	$ 1,125	$ 42	$ 1,970	$ 3,344		
TP-Overflow	$ 207	$ 1,125	$ 42	$ 500	$ 1,874		
MP	$ 207	$ 1,125	$ 42	$ 500	$ 1,874		
Mill Pond Sed Grabs (5)	-	-	$ 210	$ 2,500	$ 2,710		
CC-1	$ 207	$ 1,125	$ 42	$ 500	$ 1,874		
CC-2	$ 207	$ 1,125	$ 42	$ 500	$ 1,874		
CC-Pond	$ 207	$ 1,125	$ 42	$ 500	$ 1,874		
CC Pond Sed Grabs (5)	-	-	$ 210	$ 2,500	$ 2,710		
CCS-1	$ 207	$ 1,125	$ 42	$ 500	$ 1,874		
CCS-6	$ 207	$ 1,125	$ 42	$ 500	$ 1,874		
CCS-8	$ 207	$ 1,125	$ 42	$ 500	$ 1,874		
CCS-9	$ 207	$ 1,125	$ 42	$ 500	$ 1,874		
CCS-11	$ 207	$ 1,125	$ 42	$ 500	$ 1,874		
CCS-14	$ 207	$ 1,125	$ 42	$ 500	$ 1,874		
CCS-16	$ 207	$ 1,125	$ 42	$ 500	$ 1,874		
TOTAL	$ 6,003	$ 35,415	$ 2,562	$ 35,165	$ 79,145	2	$ 158,290

EMSL	$ 8,565	2	$ 17,130
Energy Labs	$ 70,580	2	$ 141,160

ELEMENT 2 SAMPLING
SPRING RUNOFF MONITORING

Location	EMSL	Times Collected	TOTAL
URC-1A	$ 207	15	$ 3,105
URC-2 (Rapid Turnaround)	$ 325	15	$ 4,875
LRC-1	$ 207	15	$ 3,105
LRC-2	$ 207	15	$ 3,105
LRC-6	$ 207	15	$ 3,105
FC-2	$ 207	15	$ 3,105
FC-Pond (Rapid Turnaround) (a)	$ 325	15	$ 4,875
TP (Rapid Turnaround)	$ 207	15	$ 3,105
TP-TOE1	$ 207	15	$ 3,105
TP-Overflow	$ 207	15	$ 3,105
MP (Rapid Turnaround)	$ 325	15	$ 4,875
CC-2	$ 207	15	$ 3,105
CC-Pond	$ 207	15	$ 3,105
TOTALS			$ 45,675

(a) Sample collection will be suspended after selection of the surface water toxicity test location

ELEMENT 2	$ 33,495
ELEMENT 2 SUPPLEMENTAL	$ 12,180
	$ 45,675

ELEMENT 3 SAMPLING
SUMMER AND FALL MONITORING

Location	EMSL	Times Collected	TOTAL
LRC-2	$ 207	8	$ 1,656
LRC-6	$ 207	8	$ 1,656
TOTALS			$ 3,312

COLLECTION DATES

6/23/08
7/7/08
7/21/08
8/4/08
8/18/08
9/1/08
9/15/08
9/29/08

ELEMENT 5 SAMPLING
KOOTENAI RIVER MONITORING

Location	WATER			SEDIMENT		TOTAL
	EMSL	Times	Total	EMSL	Energy Labs	
UKR	$ 207	2	$ 414			$ 414
KR-1	$ 207	2	$ 414			$ 414
KR-2	$ 207	2	$ 414			$ 414
KR-3	$ 207	2	$ 414			$ 414
KR-4	$ 207	2	$ 414			$ 414
KR-5	$ 207	2	$ 414			$ 414
KR-6	$ 207	2	$ 414			$ 414
KR-7	$ 207	2	$ 414			$ 414
KR-8	$ 207	2	$ 414			$ 414
				$ 42	$ 500	$ 542
Above RC Grab-1				$ 42	$ 500	$ 542
Below RC Grab-1				$ 42	$ 500	$ 542
Below RC Grab-2				$ 42	$ 500	$ 542
Below RC Grab-3				$ 42	$ 500	$ 542
Boring 1-1				$ 42	$ 500	$ 542
Boring 1-2				$ 42	$ 500	$ 542
Boring 1-3				$ 42	$ 500	$ 542
Boring 1-4				$ 42	$ 500	$ 542
Boring 2-1				$ 42	$ 500	$ 542
Boring 2-2				$ 42	$ 500	$ 542
Boring 2-3				$ 42	$ 500	$ 542
Boring 2-4				$ 42	$ 500	$ 542
TOTAL			$ 3,726	$ 546	$ 6,500	$ 10,772

WELL WATER REHABILITATION AND SAMPLING

	# Wells	EMSL	Times	TOTAL
Cost	$ 5	$ 207	$ 3	$ 3,105

AIR MONITORING

	# Samples	EMSL	TOTAL
Cost	96	$ 228	$ 21,888

FISH TOXICITY TESTING

	WATER			
	#	EMSL	Times	TOTAL
Cost	7	$ 207	5	$ 7,245

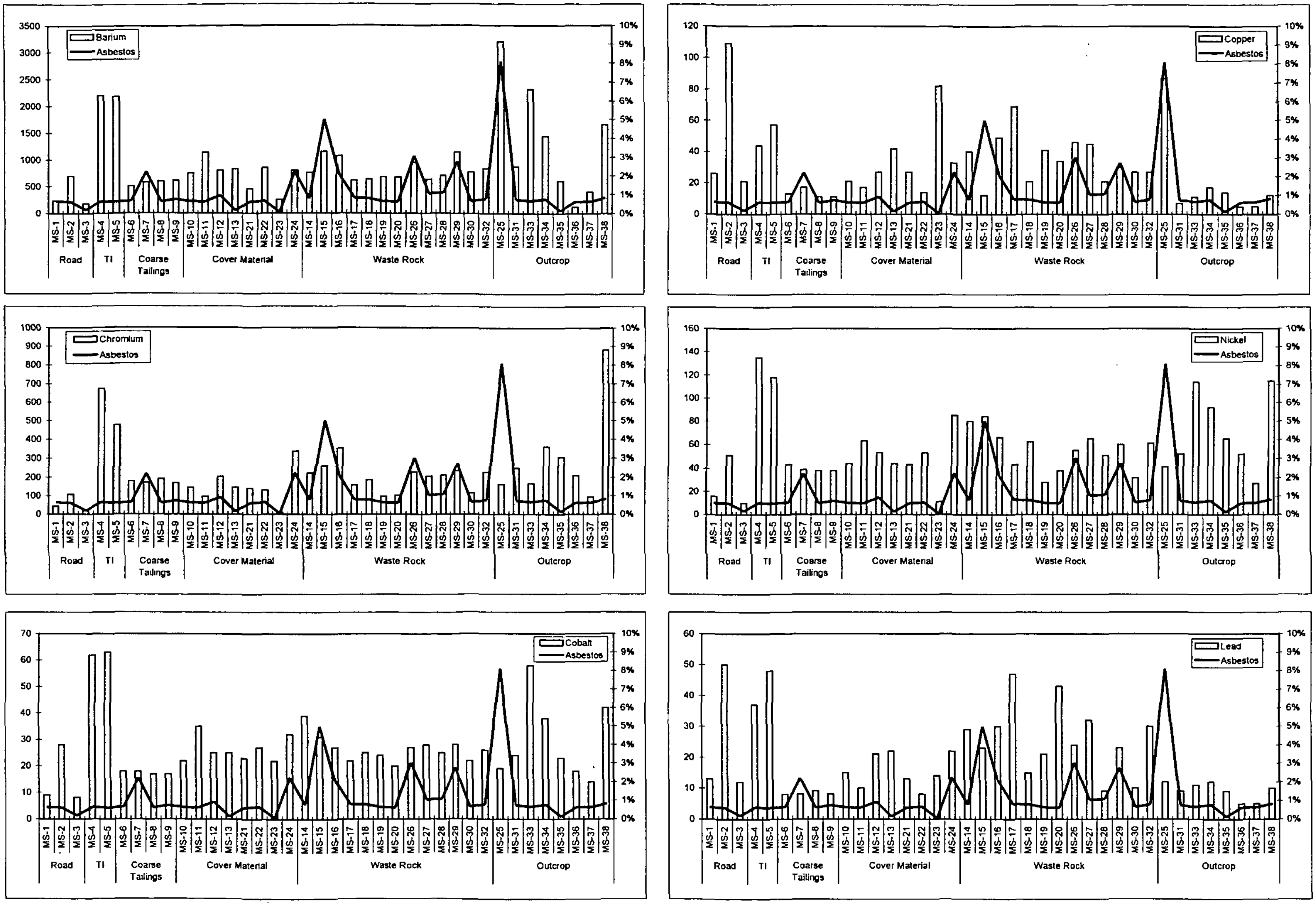
MWH
OU3 PHASE II COST ESTIMATES

	PHASE	COST
Element 1 Water and Sediment Sampling and Project Organization, Cumminication and Coordination	IIa	$ 197,097
Element 2 Surface Water Sampling and Gauging	IIa	$ 183,762
Element 2 Supplementary Water and Sediment Sampling Rounds, Element 2 Equipment and Instrumentation	IIa	$ 151,941
Element 3 Surface Water Sampling/Gauging and Storm-Event Sampling/Gauging	IIa	$ 110,561
Elements 4, 5, and Kootenai River Sampling	IIa	$ 116,114
Groundwater Well Rehabilitation and Sampling	IIb	$ 118,131
Preliminary Evaluation of Remedial Alternatives and General Environmental Services	RI	$ 58,029
Ambient Air Monitoring	IIb	$ 118,831
Total		$\boxed{\$ 1,054,466}$

MIKE CHAPMAN

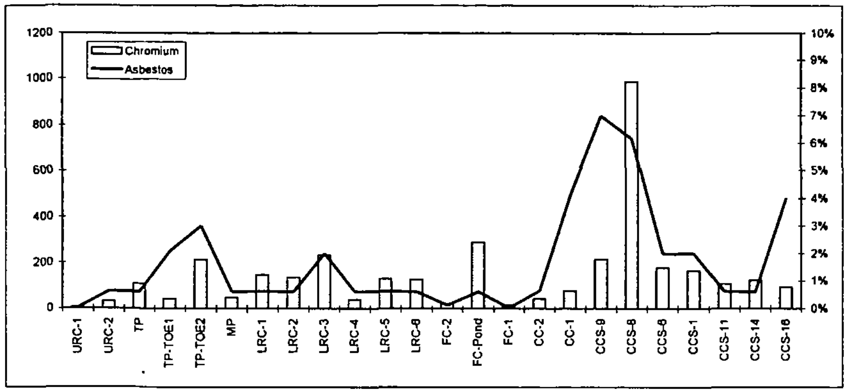
<u>ELEMENT 1</u>	
June DWP/RRM Tour	$ 200
Mill Pond Inspection	$ 100
MWH SAMPLING	$ 4,700
	$\boxed{\$\ 5{,}000}$
<u>ELEMENT 2</u>	
May Invoice	$\boxed{\$\ 30{,}000}$
<u>ELEMENT 3</u>	
8 COLLECTIONS	$\boxed{\$\ 5{,}000}$
<u>ELEMENT 4</u>	
8 COLLECTIONS	$\boxed{\$\ 7{,}000}$
<u>KOOTENAI MONITORING</u>	$\boxed{\$\ 8{,}000}$
<u>WATER WELL REHAB</u>	$\boxed{\$\ 2{,}000}$
<u>AMBIENT AIR MONITORING</u>	$\boxed{\$\ 2{,}000}$

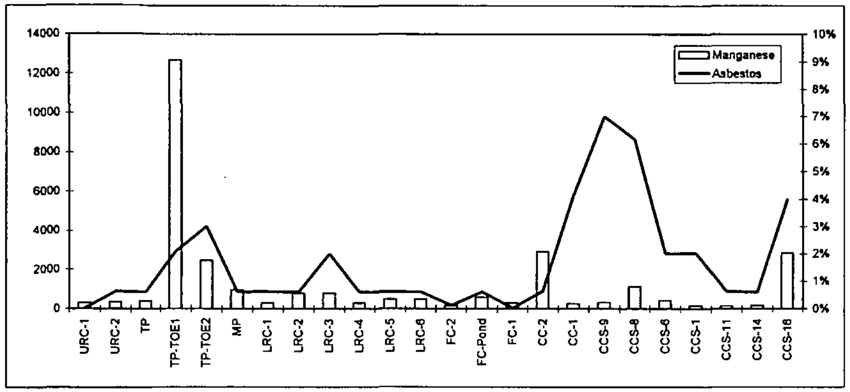
NONASBESTOS COPCs vs. ASBESTOS IN MINE WASTE

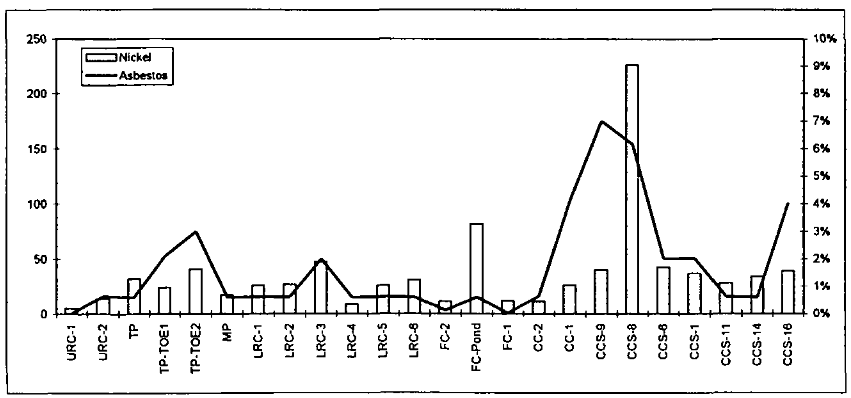


Note: These figures are only meant to compare patterns of detection between non-asbestos chemicals and LA. Non-asbestos chemicals and asbestos are plotted on different axes (different units), so the relative concentrations as shown may be deceiving.
For graphing purposes, asbestos mass fractions are based on Approach 2 combining fine and coarse fractions as outlined in Tech Memo 8.
TI = Tailings Impoundment

NONASBESTOS COPCs vs. ASBESTOS IN SEDIMENT







Note: These figures are only meant to compare patterns of detection between non-asbestos chemicals and LA. Non-asbestos chemicals and asbestos are plotted on different axes (different units), so the relative concentrations as shown may be deceiving.

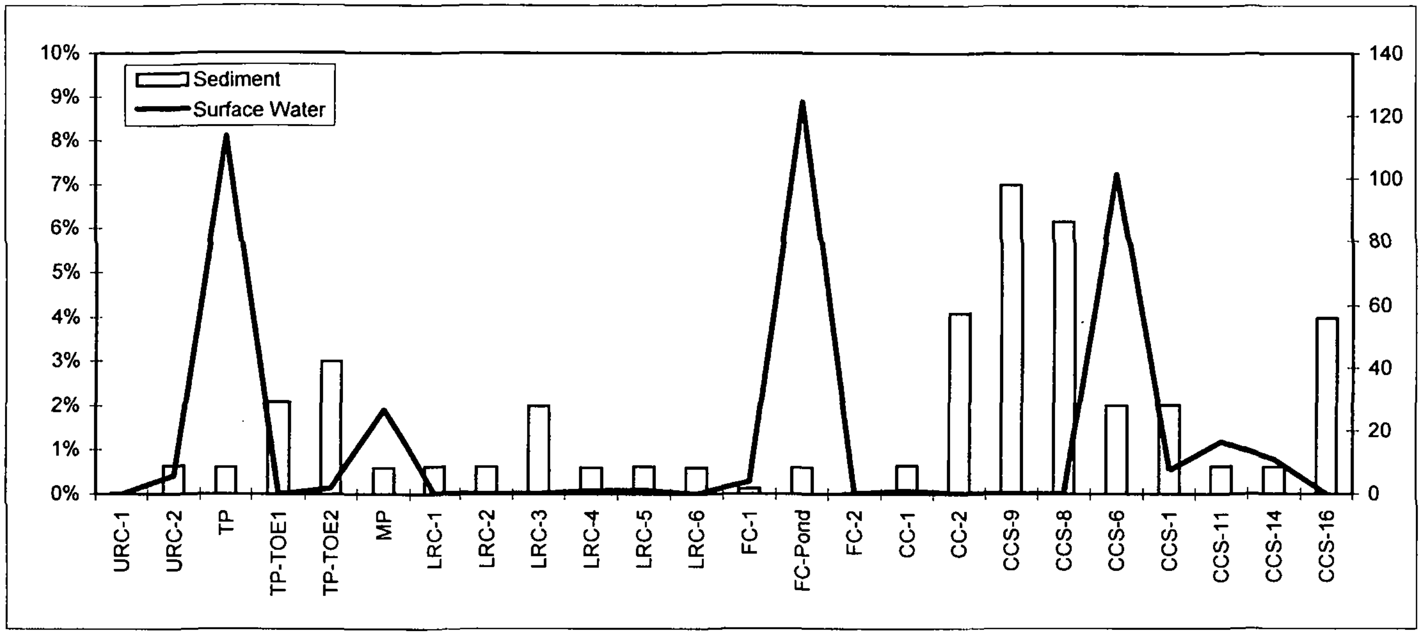
For graphing purposes, asbestos mass fractions are based on Approach 2 combining fine and coarse fractions as outlined in Tech Memo 8.

LA IN SURFACE WATER vs. SEDIMENT

Reach	Station	Concentration LA Surface Water (MFL)	Concentration LA Sediment (MF_{la}%)
Upper Rainy Creek	URC-1	<0.05	0%
	URC-2	5.76	1%
Tailings Impoundment	TP	113.56	1%
	TP-TOE1	<0.05	2%
	TP-TOE2	1.99	3%
Mill Pond	MP	26.9	1%
Lower Rainy Creek	LRC-1	0.2	1%
	LRC-2	0.1	1%
	LRC-3	0.2	2%
	LRC-4	1.05	1%
	LRC-5	1.25	1%
	LRC-6	<0.05	1%
Fleetwood Creek	FC-1	3.91	0%
	FC-Pond	124.52	1%
	FC-2	0.2	0%
Carney Creek	CC-1	0.95	1%
	CC-2	0.05	4%
Seeps	CCS-9	<0.05	7%
	CCS-8	<0.05	6%
	CCS-6	101.61	2%
	CCS-1	7.54	2%
	CCS-11	16.6	1%
	CCS-14	10.96	1%
	CCS-16	<0.08	4%

MFla% based on Approach 2 (Tech Memo 8).

LA ASBESTOS IN SURFACE WATER vs. LA ASBESTOS IN SEDIMENT



Note: These figures are only meant to compare patterns of detection between media. Surface water and sediment results are plotted on different axes (different units), so the relative concentrations as shown may be deceiving.

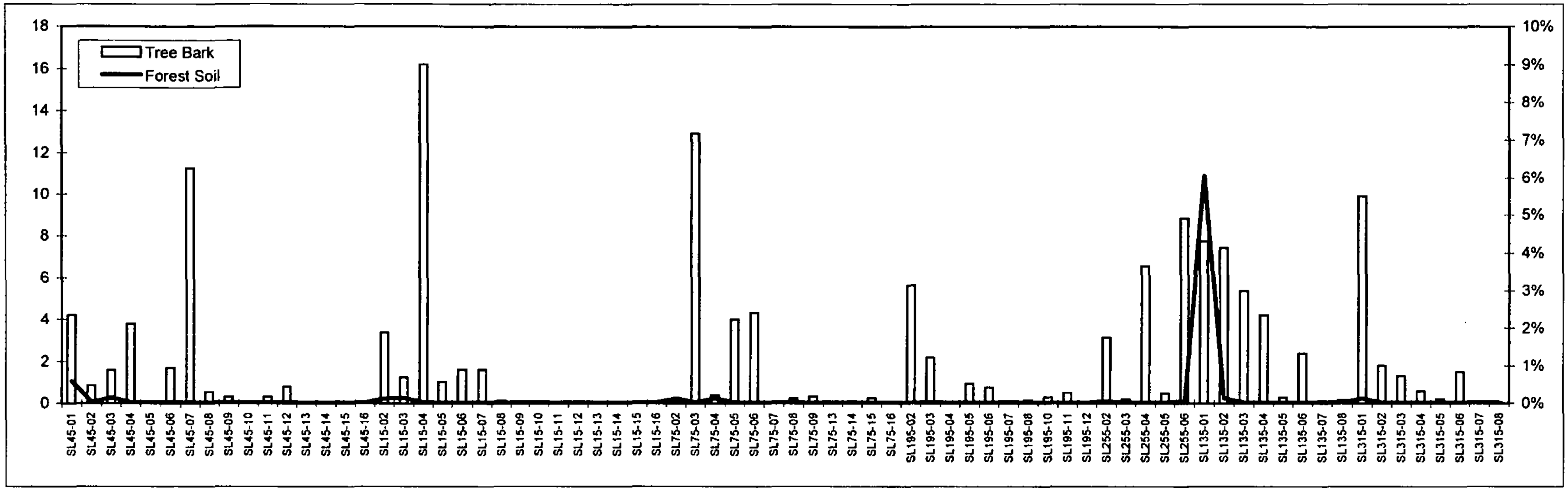
For graphing purposes, asbestos mass fractions are based on Approach 2 combining fine and coarse fractions as outlined in Tech Memo 8.

TREE BARK vs. FOREST SOIL

Transect ID	StationID	Approximate Distance From Mine (miles)	Forest Soil MF_{LA}% fine	Forest Soil MF_{LA}% coarse	Tree Bark (MS/cm^2)
SL45 Approximate downwind from mine area.	SL45-01	0.5	<1%	Tr	4.2
	SL45-02	1.0	ND	Tr	0.9
	SL45-03	1.5	Tr	Tr	1.6
	SL45-04	2.0	ND	ND	3.8
	SL45-05	2.5	ND	ND	0.0
	SL45-06	3.0	ND	ND	1 7
	SL45-07	3.5	ND	ND	11.3
	SL45-08	4.0	ND	ND	0.5
	SL45-09	4.5	ND	ND	0.3
	SL45-10	5.0	ND	ND	<DL
	SL45-11	5.5	ND	--	0.3
	SL45-12	6.0	ND	ND	0.8
	SL45-13	6.5	ND	ND	0.1
	SL45-14	7.0	ND	ND	0.0
	SL45-15	7.5	ND	ND	0.0
	SL45-16	8.0	ND	ND	<DL
SL15 30° counterclock-wise from approximate primary downwind direction	SL15-02	1.0	Tr	ND	3.4
	SL15-03	1.5	Tr	Tr	1.2
	SL15-04	2.0	ND	ND	16.2
	SL15-05	2.5	ND	--	1.0
	SL15-06	3.0	ND	ND	1.6
	SL15-07	3 5	ND	ND	1.6
	SL15-08	4.0	ND	ND	0.1
	SL15-09	4.5	ND	ND	0.1
	SL15-10	5.0	ND	ND	0.0
	SL15-11	5.5	ND	ND	<DL
	SL15-12	6.0	ND	ND	<DL
	SL15-13	6.5	ND	--	<DL
	SL15-14	7.0	ND	ND	<DL
	SL15-15	7.5	ND	ND	<DL
	SL15-16	8.0	ND	ND	<DL
SL75 30° clockwise from approximate primary downwind direction.	SL75-02	1.0	Tr	--	0.0
	SL75-03	1.5	ND	ND	12.9
	SL75-04	2.0	Tr	ND	0.4
	SL75-05	2.5	ND	ND	4.0
	SL75-06	3.0	ND	ND	4.4
	SL75-07	3.5	ND	ND	0.1
	SL75-08	4.0	ND	ND	0.2
	SL75-09	4.5	ND	ND	0.3
	SL75-13	5.0	ND	--	0.1
	SL75-14	5.5	ND	ND	0.1
	SL75-15	6.0	ND	ND	0.3
	SL75-16	6.5	ND	ND	0 1
SL195 Generally upwind of mine area/possibly downwind from Screening Plant.	SL195-02	1 0	ND	ND	5.7
	SL195-03	1.5	ND	ND	2.2
	SL195-04	2.0	ND	ND	0.0
	SL195-05	2.5	ND	ND	1.0
	SL195-06	3.0	ND	ND	0.8
	SL195-07	3.5	ND	Tr	0.1
	SL195-08	4.0	ND	ND	0.2
	SL195-10	4.5	ND	--	0.3
	SL195-11	5.0	ND	ND	0.5
	SL195-12	5.5	ND	ND	0.0
SL255 Approximate upwind direction from mine area.	SL255-02	1.0	ND	Tr	3.2
	SL255-03	1.5	ND	ND	0.2
	SL255-04	2.0	ND	ND	6 6
	SL255-05	2.5	ND	ND	0.5
	SL255-06	3 0	ND	Tr	8.8
SL135 Across-gradient from primary downwind direction.	SL135-01	0 5	0.1	0.0	7.8
	SL135-02	1.0	Tr	Tr	7.5
	SL135-03	1.5	ND	ND	5.4
	SL135-04	2 0	ND	ND	4.2
	SL135-05	2 5	ND	ND	0.3
	SL135-06	3.0	ND	ND	2.4
	SL135-07	3.5	ND	ND	0.1
	SL135-08	4 0	ND	ND	0 2
SL315 Across-gradient from primary downwind direction.	SL315-01	0 5	Tr	--	9.9
	SL315-02	1.0	ND	ND	1.8
	SL315-03	1 5	ND	ND	1.3
	SL315-04	2.0	ND	ND	0.6
	SL315-05	2.5	ND	ND	0.2
	SL315-06	3.0	ND	ND	1 5
	SL315-07	3.5	ND	ND	0.0
	SL315-08	4.0	ND	ND	0.0

ND = not detected
Tr = trace
MF = mass fraction
-- = coarse fraction was not analyzed.

LA IN TREE BARK vs. LA IN FOREST SOIL



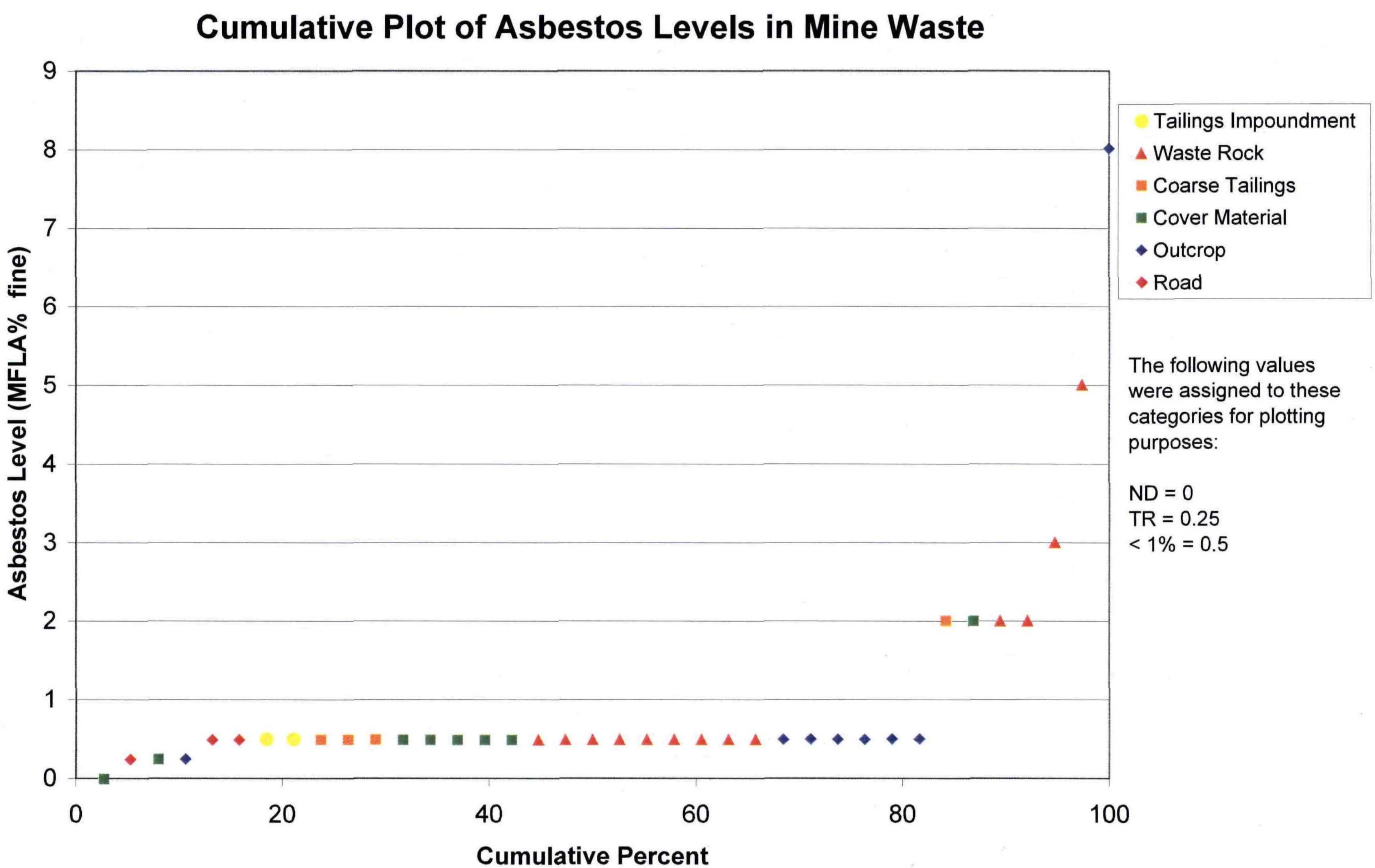
Note: These figures are only meant to compare patterns of detection between media. Tree bark and forest soil results are plotted on different axes (different units), so the relative concentrations as shown may be deceiving.

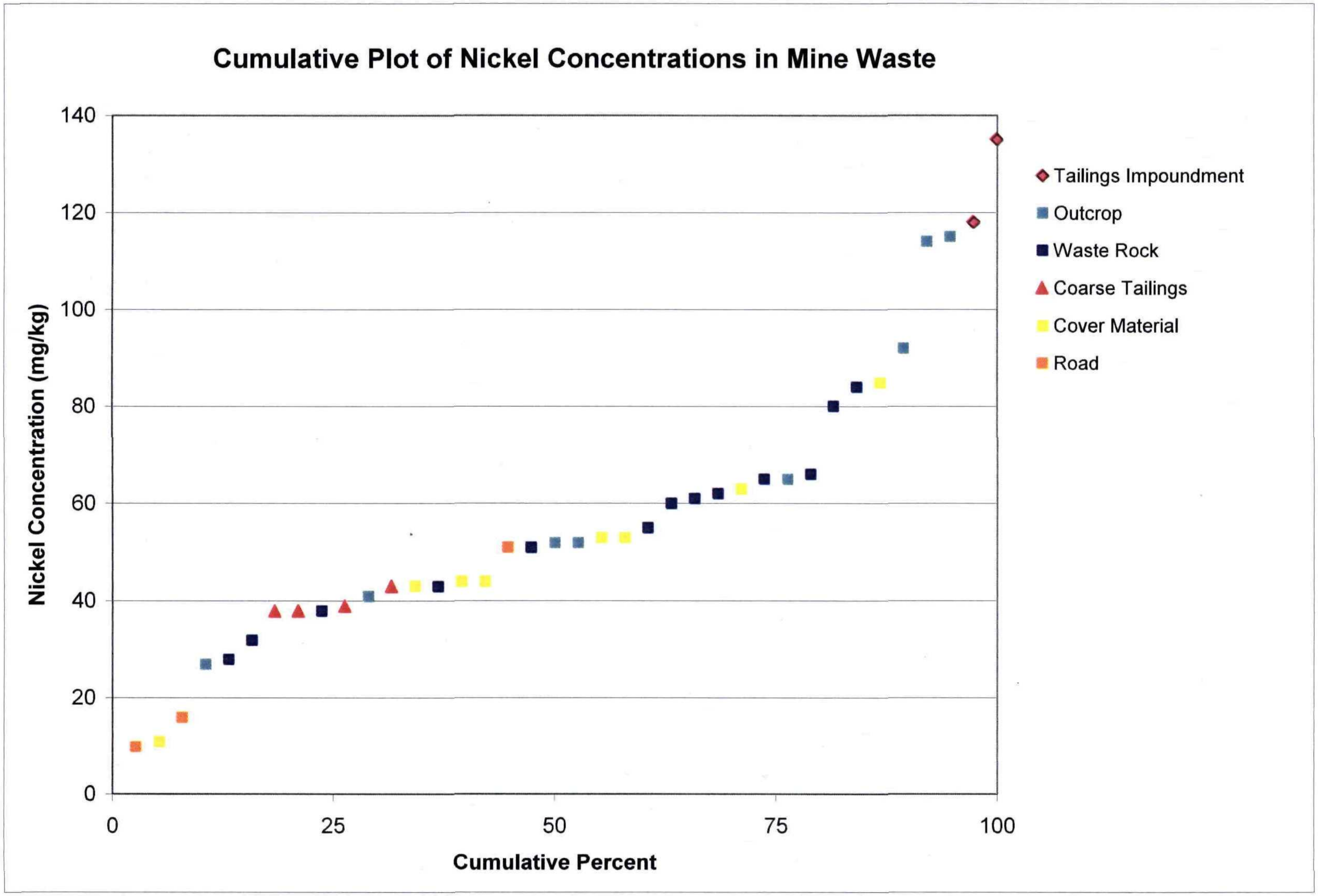
For graphing purposes, asbestos mass fractions are based on Approach 2 combining fine and coarse fractions as outlined in Tech Memo 8.

PHASE 1 RESULTS COMPARING ASBESTOS IN DUFF, FOREST SOIL, & TREE BARK

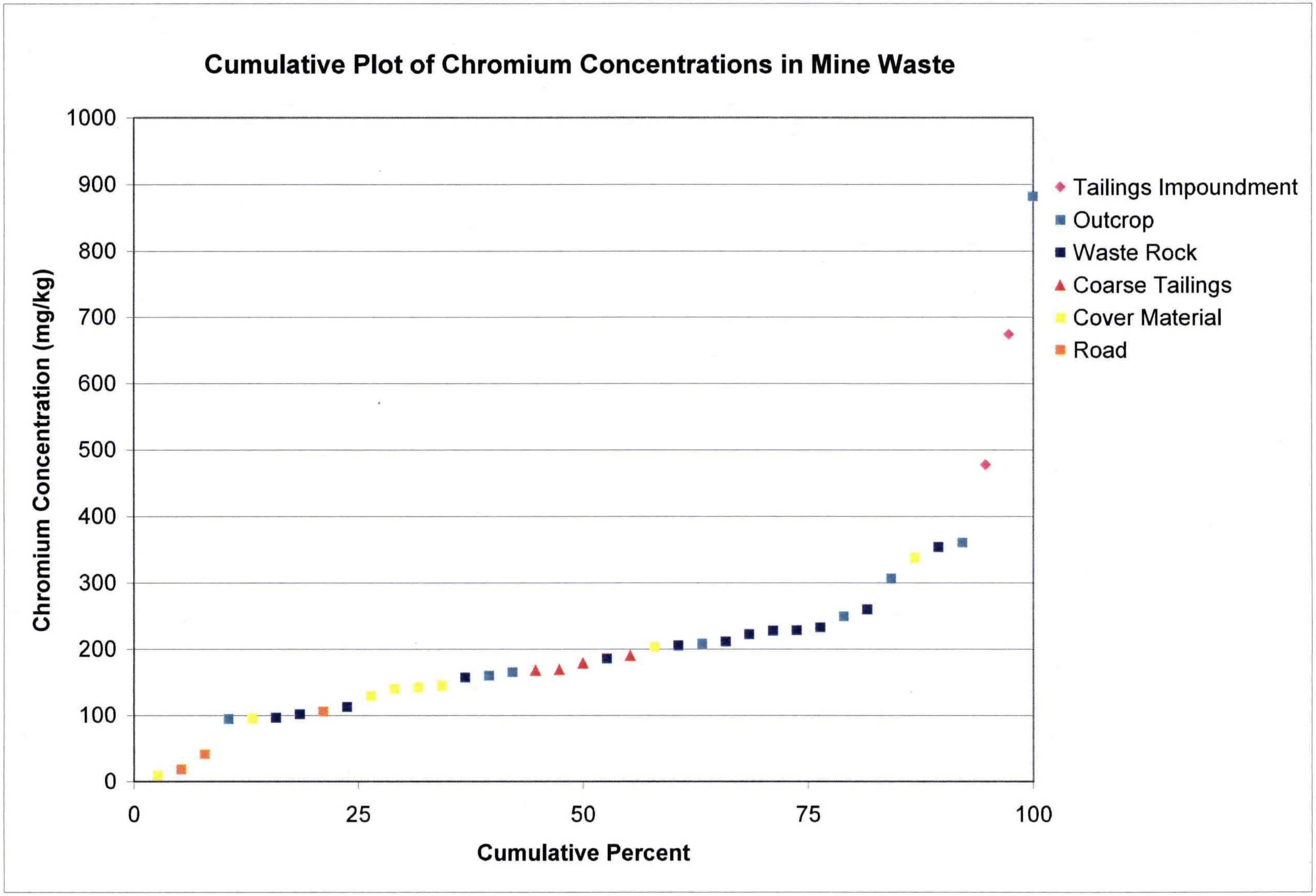
Transect ID	StationID	Approx. Distance from Mine (miles)	IndexID	DUFF RESULTS	SOIL RESULTS		TREE BARK
				Asbestos Mass (g)/ Dried Duff (g)	$MF_{LA\%}$ fine	$MF_{LA\%}$ coarse	LA Loading MS/cm^2
SL45 Approximate downwind from mine area.	SL45-01	0.5	P1-00202	0.84%	<1%	Tr	4.22
	SL45-02	1.0	P1-00222	1.74%	ND	Tr	0.86
	SL45-03	1.5	P1-00226	4.27%	Tr	Tr	1.59
	SL45-04	2.0	P1-00143	0.13%	ND	ND	3.79
	SL45-05	2.5	P1-00073	0.08%	ND	ND	0.04
	SL45-06	3.0	P1-00085	0.06%	ND	ND	1.70
	SL45-07	3.5	P1-00040	0.28%	ND	ND	11.25
SL75 30° clockwise from approximate primary downwind direction.	SL75-02	1.0	P1-00228	0.50%	Tr	--	0.04
	SL75-03	1.5	P1-00230	3.52%	ND	ND	12.91
	SL75-04	2.0	P1-00164	0.02%	Tr	ND	0.38
	SL75-05	2.5	P1-00108	0.49%	ND	ND	4.03
	SL75-06	3.0	P1-00110	0.01%	ND	ND	4.35
	SL75-07	3.5	P1-00168	0.52%	ND	ND	0.05
SL15 30° counterclock-wise from approximate primary downwind direction.	SL15-04	2.0	P1-00141	0.210%	ND	ND	16.19
	SL15-05	2.5	P1-00100	0.032%	ND	--	1.04
SL195 Generally upwind of mine area/possibly downwind from Screening Plant.	SL195-03	1.5	P1-00136	0.028%	ND	ND	2.20
	SL195-04	2.0	P1-00134	0.007%	ND	ND	0.02
SL315 Across-gradient from primary downwind direction.	SL315-03	1.5	P1-00132	0.048%	ND	ND	1.32
	SL315-04	2.0	P1-00152	0.029%	ND	ND	0.59

ND = not detected
Tr = trace
MF = mass fraction
-- = coarse fraction was not analyzed.

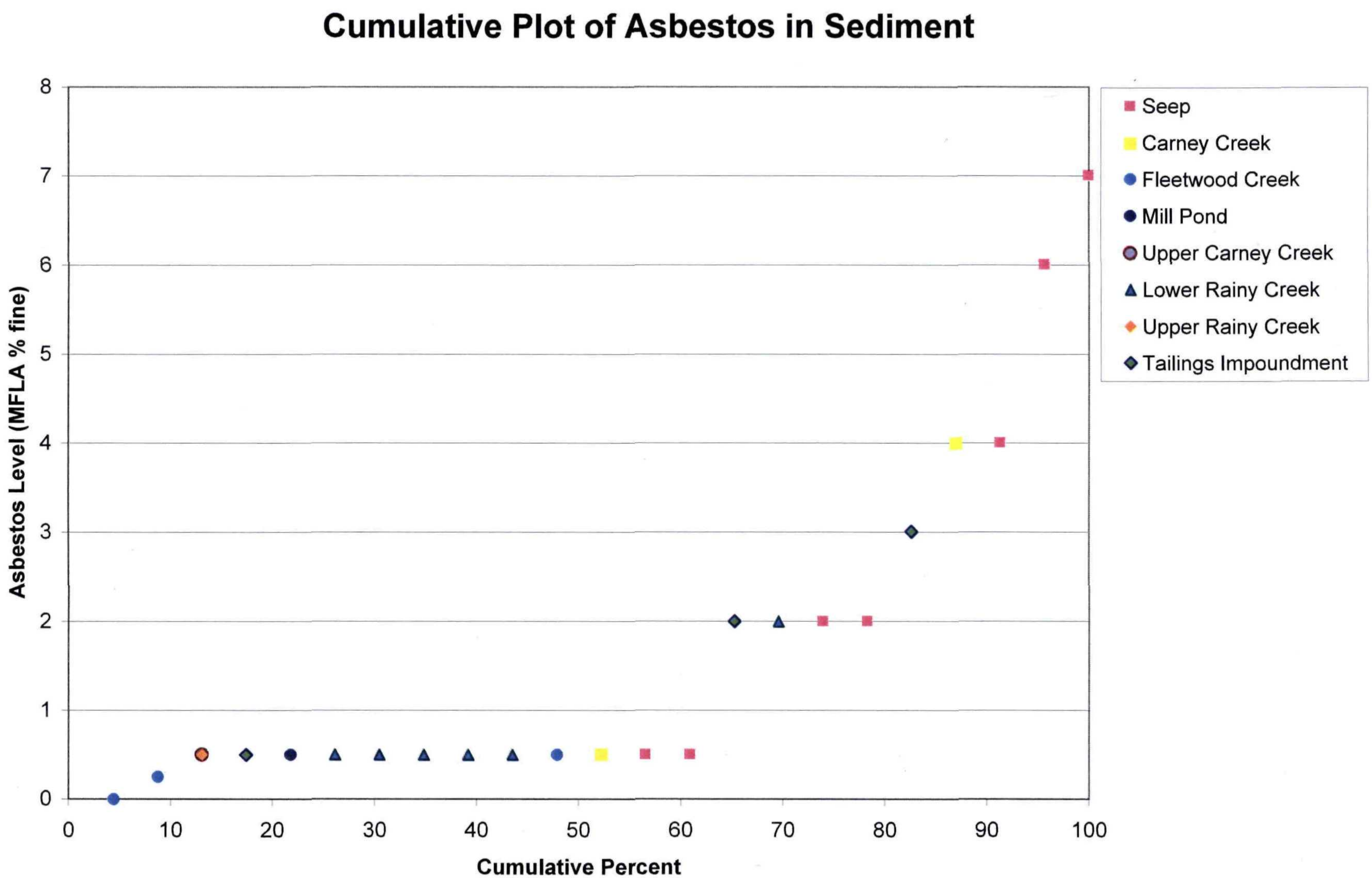

Cumulative Plot of Asbestos Levels in Mine Waste
Asbestos Level (MFLA% fine)
Cumulative Percent
0
1
2
3
4
5
6
7
8
9
0
20
40
60
80
100
Tailings Impoundment
Waste Rock
Coarse Tailings
Cover Material
Outcrop
Road
The following values were assigned to these categories for plotting purposes:
ND = 0
TR = 0.25
< 1% = 0.5



Cumulative Plot of Nickel Concentrations in Mine Waste
Nickel Concentration (mg/kg)
Cumulative Percent
0
20
40
60
80
100
120
140
0
25
50
75
100
Tailings Impoundment
Outcrop
Waste Rock
Coarse Tailings
Cover Material
Road



Cumulative Plot of Chromium Concentrations in Mine Waste
Chromium Concentration (mg/kg)
1000
900
800
700
600
500
400
300
200
100
0
0
25
50
75
100
Cumulative Percent
Tailings Impoundment
Outcrop
Waste Rock
Coarse Tailings
Cover Material
Road



Cumulative Plot of Asbestos in Sediment
Asbestos Level (MFLA % fine)
Cumulative Percent
0
1
2
3
4
5
6
7
8
0
10
20
30
40
50
60
70
80
90
100
Seep
Carney Creek
Fleetwood Creek
Mill Pond
Upper Carney Creek
Lower Rainy Creek
Upper Rainy Creek
Tailings Impoundment

List of Visitors – June 24, 2008

Purpose of visit: To attend meeting on the Libby Asbestos Superfund Site

Names of Visitors:

- Catherine LeCours – Montana Deparmtne of Environmental Quality
- Robert Medler – Remedium Group , Inc.
- Robert Marriam – Remedium Group, Inc.
- Bill Brattin – Syracuse Research Corporation
- Janet Burris – Syracuse Research Corporation
- Andy Koulermos – NewFields, Inc.

EPA point of contact:

Bonnie Lavelle - 312-6579

Ann. Occup. Hyg., Vol. 51, No. 8, pp. 717–723, 2007

doi:10.1093/annhyg/mem052

Evaluation of Asbestos Exposures during Firewood-Harvesting Simulations in Libby, MT, USA—Preliminary Data

JULIE F. HART[1]*, TONY J. WARD[2], TERRY M. SPEAR[1], KELLY CRISPEN[2] and TARA R. ZOLNIKOV[1]

[1]*Department of Safety, Health and Industrial Hygiene, Montana Tech of The University of Montana, Butte, MT, USA;* [2]*Center for Environmental Health Sciences, The University of Montana, Missoula, MT, USA*

Received 22 May 2007; in final form 14 September 2007; published online 7 November 2007

Research was conducted in order to assess potential exposure to asbestos while harvesting firewood from amphibole-contaminated trees near Libby, MT, USA. Three firewood-harvesting simulations took place in the summer and fall of 2006 in the Kootenai Forest inside the US Environmental Protection Agency (EPA) restricted zone surrounding the former W.R. Grace vermiculite mine. Another simulation was conducted near Missoula, MT, USA, which served as the control. The work practices following each simulation were consistent throughout each trial. Personal breathing zone (PBZ) asbestos concentrations were measured by phase contrast microscopy (PCM) and transmission electron microscopy (TEM). Surface wipe samples of personal protective clothing were measured by TEM. The mean (n = 12) PBZ PCM sample time-weighted average (TWA) concentration was 0.29 fibers per milliliter, standard deviation (SD = 0.54). A substantial portion (more than five fibers per sample) of non-asbestos fibers (cellulose) was reported on all PBZ samples (excluding field blanks) when analyzed by TEM. The mean (n = 12) PBZ TEM sample TWA concentration for amphibole fibers <5-μm long was 0.15 fibers per milliliter (SD = 0.21) and the mean (n = 12) PBZ TEM concentration for amphibole fibers >5-μm long was 0.07 fibers per milliliter (SD = 0.08). Substantial amphibole fiber concentrations were revealed on Tyvek® clothing wipe samples. The mean concentration (n = 12) was 29 826 fibers per square centimeter (SD = 37 555), with 91% (27 192 fibers per square centimeter) comprised fibers <5-μm long. There were no significant differences in PBZ and wipe sample concentrations among the tasks performed by four investigators. Each of these three simulations were consistent in demonstrating that amphibole fibers are released from tree reservoirs during firewood-harvesting activities in asbestos-contaminated areas and that the potential for exposure exists during such activities.

Keywords: amphibole; asbestos; electron microscopy; fibers; Libby; Montana; tree bark

INTRODUCTION

For 70 years, a mining operation located 7 miles northeast of Libby, MT, USA, may have supplied 80% of the world's vermiculite (USEPA, 2007). In the early 1920s, Dr Edward Alley founded the Zonolite Company in Libby. Soon after, the mine and processing facility at Vermiculite Mountain (also known as Zonolite Mountain) was developed. W.R. Grace purchased the site in 1963 and continued operation of the mine until 1990.

Vermiculite was mined and processed primarily for use as building insulation and as a soil conditioner. However, in the case of the Libby ore, it proved to be a hazardous resource. Throughout the deposit, veins of vermiculite ore were contaminated with a toxic form of naturally occurring fibrous, asbestiform amphibole (Pardee and Larsen, 1929). Today, many areas surrounding the abandoned surface mine and decommissioned processing facilities are contaminated with amphibole fibers as well as are many of the homes within the Libby area.

Former Libby mine and mill workers exposed to amphibole fibers have a high incidence of pleural plaques, asbestosis, lung cancer and mesothelioma

*Author to whom correspondence should be addressed.
Tel: +406-496-4792; fax: +406-496-4650;
e-mail: jhart@mtech.edu

(McDonald et al., 1986; Amandus and Wheeler, 1987; Amandus et al., 1987; Dearwent et al., 2000; Peipins, 2003). The relationship between mesothelioma and asbestos exposure has been adequately explored, with at least 70% of mesothelioma cases reported in direct correlation to asbestos exposure (Hammond et al., 1965; McDonald and McDonald, 1977, 1980; McDonald et al., 1986; NCI, 2005). Furthermore, asbestosis mortality in the Libby area was found to be 40–80 times higher than the expected; and lung cancer was found to be 20–30% higher than the expected (ATSDR, 2003).

It has recently been discovered that tree bark samples collected within the town of Libby, within the EPA-restricted mine area and along the railroad corridor west of town also contain varying levels of amphibole contamination (Ward et al., 2006). Analyses to date have yielded substantial amphibole fiber concentrations ranging from 41 to 530 million fibers per gram of bark, while a bark sample collected ~11 kilometers west of town along the railroad line had concentrations of 19 million fibers per gram. A conversion of these mass-based concentrations to areal concentrations (to reflect surface area contamination) revealed concentrations in excess of 100 million amphibole fibers per square centimeter.

In addition to vermiculite mining, much of the economy in Libby has historically been supported by the harvesting and processing of timber. Western Montana logging companies own ~315 000 acres of land surrounding the Libby mine that could potentially be harvested. Because firewood is the cheapest source of fuel in the Libby area, it is the most common source of residential heating during the cold Libby winters. There are an estimated 1300 wood stoves in use in Libby, with at least some of the firewood being harvested within the Libby valley and surrounding forests.

Previous results from tree bark sampling suggest a potential for asbestos exposure to those who harvest or disturb contaminated wood within the Libby area (Ward et al., 2006). Despite the reliance on local timber resources in Libby, currently no definitive efforts exist to evaluate the potential for asbestos exposure during the common practice of harvesting firewood for residential home heating. The research within this study presents preliminary data that evaluate the potential of amphibole exposure associated with firewood harvesting within a known asbestos-contaminated area. Research trials were conducted inside the Libby EPA-restricted zone where amphibole contamination in tree bark was previously demonstrated (Ward et al., 2006).

METHODS

During the summer and fall of 2006, three separate firewood-harvesting simulations were conducted on US Forest Service property in an area of the Kootenai Forest inside the EPA-restricted zone surrounding the former W.R. Grace vermiculite mine. These trials were conducted ~30 to 35 m off of Rainy Creek road ~1.5 km up Rainy Creek road from Highway 37 (Fig. 1). Another simulation was conducted near Missoula, MT, USA (~4 h southeast of Libby) to serve as a control.

All the investigators participating in this study completed a 40-h Occupational Safety and Health Administration (OSHA) Hazardous Waste Operations and Emergency Response course or demonstrated competency via education and/or professional certifications (industrial hygiene PhD, certified industrial hygienist). In addition, investigators participated in a training/planning session developed specifically for the harvest simulations. A site safety and health plan was also written and submitted to the Libby EPA supervisor for approval. All investigators obtained medical clearance to wear negative pressure respiratory protection and passed quantitative fit tests within the past year.

Trees selected for the harvesting simulation at each site consisted of three to four standing dead and three to four downed trees. The location of each simulation site was identified and recorded using a Garmen Etrex 12 channel global positioning system. Tree species were identified and documented. Prior to harvesting, a minimum of one 200-gm bark sample was collected from two sides of each tree ~1.2 m from the base. Additional bark samples were collected from randomly selected harvested trees at 1.2 m intervals from the base to the treetop. The bark was collected by prying off sections with a small pry bar and placing them in labeled plastic bags. The bags were then sealed and labeled and the pry bar was cleaned with a wet wipe after each collection. The bark samples were preserved for later analysis by transmission electron microscopy (TEM).

New Poulan® model 3416 gas chain saws were used for each research simulation trial. The chain saw was replaced prior to each trial in order to avoid cross-contamination and to ensure that the condition of the chain (sharpness) remained consistent. The harvesting simulation process at each site consisted of downing the tree, removing tree branches and sawing the log into 30-cm-long blocks. The blocks were then gathered and stacked in a pile ~20 m away. Four to five investigators participated in each simulation trial, with the work practices employed by each investigator remaining consistent throughout each of the trials. One investigator operated a chain saw, while a second investigator assisted the chain saw operator by clearing debris, moving downed trees and holding downed trees steady while being sawed. Two investigators gathered the wood blocks and stacked them into piles. An additional investigator was present for trials 2 and 3 and served as a data recorder.

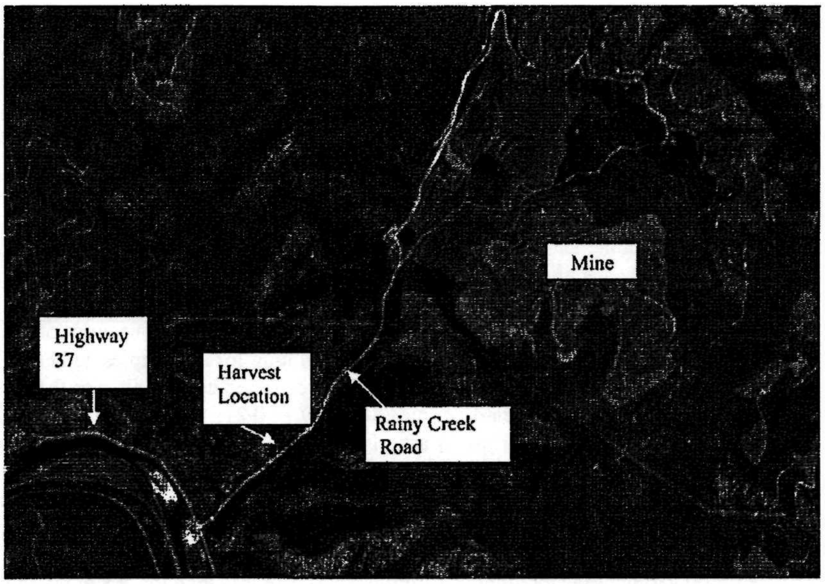


Fig. 1. Location of the 2006 firewood-harvesting simulations conducted off Rainy Creek road, near the former vermiculite site in the EPA-restricted zone near Libby, MT, USA. The distance from Highway 37 to the Harvest Location was ~1.5 km.

Personal breathing zone (PBZ) samples were collected during the trials using non-conductive three-piece asbestos sampling cassettes. The cassettes contained 25 mm, 0.8 μm pore size mixed cellulose ester membrane filters. SKC Aircheck 224 sampling pumps were calibrated before and after each trial with a Gilian® Gilibrator 2 primary flow meter at a flow rate of 4 l min^{-1}. Throughout each trial, each investigator wore a sampling pump with the asbestos cassette placed in the breathing zone. PBZ samples were analyzed for fibers per National Institute for Occupational Safety and Health's Manual of Analytical Method 7400, Asbestos and Other Fibers by phase contrast microscopy (PCM) (NIOSH, 1994) and for asbestos per EPA's Asbestos Hazard Emergency Response Act's (AHERA), Airborne Asbestos by TEM (USEPA, 1987). AHERA requires selected area electron diffraction and energy dispersive X-ray analysis to determine mineral type and elemental composition (asbestos types). AHERA analysis was enhanced by recording individual fiber dimensions rather than classifying them into two size categories. Fibers classified as 'actinolite/tremolite' also included the winchite/richterite fibers characterized by Meeker *et al.* (2003).

All air samples were analyzed by DataChem Laboratories (Cincinnati, OH, USA), a laboratory accredited by the American Industrial Hygiene Association (PCM), the National Voluntary Laboratory Accreditation Program (TEM) and the New York State Department of Health Environmental Laboratory Approval Program (PCM and TEM). PBZ samples submitted included 10% field blanks.

In addition to PBZ sampling, surface wipe sampling of the outer layer of Tyvek® clothing was conducted at the conclusion of each trial. The wipe sampling protocol followed the American Society for Testing and Materials (ASTM) D 6480-05 procedures, Wipe Sampling for Settled Asbestos (ASTM, 2006). Wipes were collected with SKC Ghost Wipes pre-moistened with deionized water. A 10 by 10 cm SKC disposable manila paper template was used for each wipe. A wipe sample was gathered on each investigator's chest and upper thigh. The site of the chest wipe sample and thigh sample (right/left) was randomly selected. The two wipe samples collected for each investigator were submitted for analysis as a composite sample. In addition to the post-harvest wipes collected, pre-harvest wipes, inner layer Tyvek wipes and 10% field blanks were analyzed. The wipe samples were analyzed for asbestos per ASTM's D 6480-05 Method, TEM Asbestos Analysis (ASTM, 2006) by DataChem.

The average duration of each firewood harvest simulation was 89 min, with 45–50 min dedicated to the harvest simulations and the remaining time associated with bark collection. The harvest duration was limited to minimize the potential to overload the sample media.

RESULTS AND DISCUSSION

Multiple tree bark samples were collected from standing dead or fallen trees selected for harvesting during both the control harvest in Missoula and the firewood-harvesting simulations conducted within the Libby restricted zone. The samples were collected from common coniferous tree types [lodgepole pine (*Pinus contorta*), ponderosa pine (*Pinus ponderosa*), larch (*Larix occidentalis*) and Douglas fir (*Pseudotsuga menziesii*)] found within the area and are representative of the types of trees typically burned during residential home heating in western Montana. Amphibole fibers were not detected in bark samples collected from Missoula, MT, USA. Eight bark samples analyzed to date from the Libby EPA-restricted zone (collected in the same area where the firewood-harvesting simulations were conducted) revealed substantial amphibole fiber concentrations ranging from 7 to 97 million fibers per square centimeter of bark surface area. These concentrations are consistent with amphibole contamination in tree bark previously reported by Ward *et al.* (2006). Fiber dimension analyses of the bark samples revealed that the majority of the asbestos fibers detected were <5 microns in length. Results from the bark samples collected in these trials showed that all identified fibers were typical of the Libby vermiculite amphibole contaminants, with typical elemental composition of Si > Mg > Ca > Fe > Na > K (Meeker *et al.*, 2003). There were no length-based differences in the elemental composition of fibers.

PBZ samples collected during the firewood-harvesting trials were analyzed for asbestos by both PCM and AHERA TEM. Fibers were observed on all samples analyzed by PCM, excluding field blanks. The PCM fiber concentrations from the control (Missoula) trial ranged from 0.01 to 0.02 fibers per milliliter. The National Institute for Occupational Safety and Health (NIOSH) PCM method cannot identify fiber types (Dodson and Hammar, 2006), but AHERA TEM analysis revealed fibers in the control samples to be organic, non-asbestos (cellulose), with no asbestos concentrations above the AHERA TEM analytical sensitivity (AS) of (0.009–0.01 structures per milliliter).

Table 1 presents PBZ air sampling results, including the mean PBZ asbestos concentrations (measured by PCM and AHERA TEM, respectively) and the standard deviation (SD) from the three harvest trials per task (chain saw operator, operator assistant and wood stackers 1 and 2). While the PBZ sample from the chain saw operator's assistant revealed the highest mean total asbestos concentration (column 5, Table 1), overall no significant differences were observed in PBZ asbestos concentrations between tasks.

Differences were observed in the concentration of shorter fibers (<5 μm long) compared to the concentration of longer fibers (>5 μm long) ($P = 0.055$) for PBZ air samples. The mean concentration of asbestos fibers <5 μm long for all samples gathered from the Libby EPA-restricted zone trials was 0.15 fibers per milliliter, SD = 0.21, while mean concentration of asbestos fibers >5 μm long for all samples gathered from the Libby EPA-restricted zone trials was 0.07 fibers per milliliter SD = 0.08 (row 6, Table 1). Three of 12 analyses for fibers >5 μm long from the Libby EPA-restricted zone trials revealed concentrations that were less than the AS of 0.0148, 0.0145 and 0.0148 fibers per milliliter, respectively. In order to perform statistical analysis on concentrations that were less than the AS, a value equal to the AS divided by the square root of 2 was used (Hornung and Reed, 1990).

In terms of fiber counts reported by the laboratory (not shown), 69% of the fibers collected on PBZ samples were <5 μm long. This is consistent with ambient air sampling trends reported for Libby (ATSDR, 2003).

Due to the lack of public exposure limits for asbestos applicable to this situation, PBZ concentrations were compared with occupational exposure limits. The current occupational 8-h time-weighted average (TWA) exposure limit for asbestos is 0.1 fiber per milliter for fibers >5 μm in length, with an aspect ratio (length:width) ≥3:1, as determined by PCM (OSHA, ACGIH, 2001). The NIOSH recommended exposure limit for asbestos is identical except that it is based on a 10-h TWA (NIOSH). In addition to

Table 1. Mean PBZ air sampling results reported in fibers per milliliter (f/ml) and SDs from three firewood harvest simulation trials conducted in the EPA-restricted zone near Libby, MT, USA

Task performed	Mean PCM sample TWA (f/ml)	Mean TEM sample TWA (f/ml) <5 μm	Mean TEM sample TWA (f/ml) >5 μm	Mean TEM sample TWA (f/ml) total asbestos
Chain saw operator, $n = 3$	0.72 (1.06)	0.07 (0.03)	0.04 (0.03)	0.11 (0.06)[a]
Operator assistant, $n = 3$	0.26 (0.32)	0.26 (0.37)	0.14 (0.14)	0.40 (0.51)[a]
Wood stacker 1, $n = 3$	0.07 (0.06)	0.09 (0.12)	0.04 (0.05)[b]	0.13 (0.17)
Wood stacker 2, $n = 3$	0.12 (0.10)	0.19 (0.24)	0.05 (0.07)[c]	0.24 (0.31)
Total mean for all tasks, $n = 12$	0.29 (0.54)	0.15 (0.21)	0.07 (0.08)	0.22 (0.29)

Results are reported by task performed (chain saw operator, operator assistant and wood stackers 1 and 2).
[a]One of three samples had loose material on the filter and was prepared using an indirect preparation method.
[b]Two samples were less than the AS of 0.0145 and 0.0148 structures per milliliter, respectively. AS divided by the square root of 2 was used to calculate mean concentration.
[c]One sample was less than the AS of 0.0148 structures per milliliter. AS divided by the square root of 2 was used to calculate mean concentration.

the TWA permissible exposure limit, OSHA has defined an excursion limit of 1.0 fiber per milliliter averaged over a sampling period of 30 min.

For individual PBZ harvest trial samples for fibers >5 μm (not shown in Table 1), two of three samples from both the chain saw operator and the operator's assistant exceeded the OSHA exposure limit of 0.1 fiber per milliliter, assuming an 8-h exposure duration, while one of three PBZ samples from both of the wood stackers exceeded the OSHA exposure limit assuming an 8-h exposure duration when analyzed by PCM.

A substantial portion of cellulose (from sawdust) fibers was expected in PCM analyses. AHERA TEM analyses were performed to describe the fiber population. In terms of fiber counts reported by the laboratory (not shown in Table 1), more than five non-asbestos fibers (organic, gypsum) were identified on all PBZ AHERA TEM samples. AHERA TEM analyses for the concentration of asbestos fibers >5 μm revealed that 3 of 12 samples exceeded the OSHA PEL, assuming an 8-h exposure duration (not shown in Table 1). These samples were collected on the chain saw operator's assistant and wood stackers 1 and 2 during the firewood harvest trial 3.

The current regulatory methods of counting fibers based on fiber length and aspect ratio may not adequately describe the risk of asbestos-related health effects. Fiber size, shape and composition contribute collectively to health risks in ways that are currently being evaluated (ATSDR, 2003). Although we compared concentrations of asbestos >5 μm to occupational exposure limits, the concentrations of fibers <5 μm may contribute to health risks.

Surface wipe sampling of the outer layer of Tyvek clothing was conducted at the conclusion of each trial. These wipe samples were analyzed for asbestos fibers by TEM with results presented in Table 2. All the field blank, inner layer Tyvek and pre-harvest outer layer Tyvek wipe samples showed no asbestos contamination and were below the AS (878 structures per square centimeter) for the D 6480-05 TEM method. There was a striking difference between the sizes of the asbestos fibers (length) measured from the suits following the firewood-harvesting simulations, with significant concentrations of the shorter fibers (<5 μm) found when compared to longer fibers (>5 μm in length) ($P = 0.038$). The mean concentration of asbestos fibers <5 μm long for all Libby restricted zone post-harvest wipe samples was 27 192 fibers per square centimeter, SD = 36 749. The mean concentration of fibers >5 μm in length for all Libby restricted zone post-harvest wipe samples (and for each job description) was more consistent compared to the smaller fibers detected, with 2634 fibers per square centimeter (SD = 1983) measured. One of 12 wipe sample analyses for fibers >5 μm long revealed concentrations that were less than the AS of 5270 fibers per square centimeter. In order to perform statistical analysis on concentrations that were less than the AS, a value equal to AS divided by the square root of 2 was used (Hornung and Reed, 1990).

Wipe samples collected from the chain saw operator and the chain saw operator's assistant after harvest trial 1 showed concentrations of asbestos fibers <5 μm long at least six times the asbestos wipe concentrations measured from the two wood stackers

Table 2. TEM wipe sampling results from three firewood harvest simulation trials conducted in the Libby EPA-restricted zone near Libby, MT, USA

Task performed	Harvest trial	TEM (f/cm^2) <5 μm	TEM (f/cm^2) >5 μm	TEM (f/cm^2) total asbestos
Chain saw operator	1	100 123	3726[a]	103 849
	2	4830	878	5708
	3	15 848	4953	20 801
Operator assistant	1	108 905	3513	112 418
	2	5709	439	6148
	3	14 134	2827	16 961
Wood stacker 1	1	16 863	2108	18 971
	2	5709	439	6148
	3	14 135	3392	17 527
Wood stacker 2	1	6324	2108	8432
	2	6587	439	7026
	3	27 140	6785	33 925
Total mean for all tasks, $n = 12$		27 192 (36 749)	2634 (1983)	29 826 (37 555)

Results are reported by task performed (chain saw operator, operator assistant and wood stackers 1 and 2). f/cm^2 = fibers per centimeter square.

[a]One sample was less than the AS of 5270 structures per square centimeter. AS divided by the square root of 2 was used to calculate mean concentration.

(column 3, Table 2). However, this same trend was not observed for harvest trials 2 and 3. There were no statistically significant differences observed in wipe asbestos concentrations between the four investigators.

CONCLUSION

Results from the firewood-harvesting simulations conducted within this study indicate that amphibole fibers can become liberated from trees when harvesting firewood in asbestos-contaminated areas. Bark samples collected in the same area where the firewood-harvesting simulations were conducted revealed substantial amphibole fiber concentrations ranging from 7 to 97 million fibers per square centimeter of bark surface area. The majority of the PBZ samples collected during the EPA-restricted zone harvest simulations showed concentrations above analytical sensitivities (21 of 24 samples), while PBZ samples collected during a control harvest simulation did not detect asbestos fibers above TEM analytical sensitivities. A higher concentration of shorter fibers (<5 μm) was observed on the PBZ air samples compared to longer fibers (>5 μm), and the task performed by each investigator was not a factor in their PBZ exposures. The wood stackers had PBZ exposures comparable to the investigators much closer to the source; i.e. the chain saw operator and the chain saw operator's assistant. The lack of difference in exposure between the investigators indicates that the plume was not narrowly localized.

In addition to the airborne exposure potential associated with harvesting amphibole-contaminated trees, there is also a strong potential for clothing contamination. Wipe samples collected from the investigators' chest and thigh revealed asbestos fiber contamination above the AS in 23 of 24 samples. Clothing contamination may serve as a secondary source of exposure to those that harvest amphibole-contaminated wood. In addition, family members, etc., not directly exposed to asbestos during firewood harvests, may be exposed while laundering contaminated clothing. As noted with PBZ samples, there were no significant differences in wipe sample concentrations between the four investigators. And, consistent with the PBZ samples, a higher concentration of fibers <5 μm was observed on the wipe samples compared to longer fibers (>5 μm).

The authors recognize that the firewood-harvesting simulations presented in this study represent near worst-case scenarios. The study was conducted on US Forest Service land within the EPA-restricted zone. This area is currently secured and not available to the public for firewood harvesting. However, areas within the Libby EPA-restricted zone have historically been utilized for public firewood harvesting and commercial logging. Amphibole contamination in tree bark has been demonstrated in areas near Libby that are outside of the Libby EPA-restricted zone. The results of this study suggest that similar exposure potentials may exist to members of the public when harvesting firewood or to commercial loggers working in the Libby area. Further studies are needed to address the degree of amphibole contamination in tree species outside of the Libby EPA-restricted zone and the related risk to members of the public as well as occupational exposure groups.

FUNDING

The National Institutes of Health Centers of Biomedical Research Excellence (p20-RR017670).

Acknowledgements—The authors thank US EPA Region 8 and Forest Service Kootenai District for granting access to the restricted mine area. We thank Dr James Webber (Wadsworth Center) for his contributions to this project and our asbestos research projects at The University of Montana and Montana Tech. We also thank Anna Marie Ristich (DataChem Laboratories) and Dr Richard Douglass (Montana Tech) for their intellectual contributions.

REFERENCES

Agency for Toxic Substances and Disease Registry (ATSDR). (2003) Public health assessment, Libby asbestos NPL site, OU4: screening plant, export plant, town of Libby and affected Libby valley residential and commercial properties; Available at http://www.atsdr.cdc.gov/NEWS/libby-pha.pdf.

Amandus HE, Wheeler R. (1987) The morbidity and mortality of vermiculite miners and millers exposed to tremolite-actinolite: part II. Mortality. Am J Ind Med; 1: 15–26.

Amandus HE, Wheeler PE, Jankovic J *et al.* (1987) The morbidity and mortality of vermiculite miners and millers exposed to tremolite-actinolite: part I. Exposure estimates. Am J Ind Med; 11: 1–14.

American Conference of Governmental Industrial Hygienists (ACGIH). (2007) TLVs® and BEIs® Based on the documentation of the threshold limit values for chemical substances and physical agents. Cincinnati, OH: ACGIH.

American Society for Testing and Materials Standards (ASTM). (2006) D6480–05 standard test method for wipe sampling of surfaces, indirect preparation, and analysis for asbestos structure number concentrations by transmission electron microscopy. ASTM International. Available at http://www.astm.org/cgi-bin/SoftCart.exe/DATABASE.CART/REDLINE_PAGES/D6480.htm?L+mystore+ehme8257+1175904007.

Dearwent S, Imtiaz R, Metcalf S *et al.* (2000) Health consultation—mortality from asbestosis in Libby, Montana. Agency for Toxic Substances and Disease Registry. Available at http://www.atsdr.cdc.gov/HAC/pha/libby/lib_toc.html.

Dodson RF, Hammar SP. (2006) Asbestos—risk assessment, epidemiology, and health effects. Boca Raton, FL: CRC Press; pp. 14.

Hammond E, Selikoff IJ, Churg J. (1965) Neoplasia among insulation workers in the United States with special reference to intra-abdominal neoplasia. Ann N Y Acad Sci; 132: 519–25.

Hornung RW, Reed LD. (1990) Estimation of average concentration in the presence of nondetectable values. Appl Occup Environ Hyg; 5: 46–51.

McDonald AD, McDonald JC. (1980) Malignant mesothelioma in North America. Cancer; 46: 1650–6.

McDonald JC, McDonald AD. (1977) Epidemiology of mesothelioma from estimated incidence. Prev Med; 6: 426–46.
McDonald JC, McDonald AD, Armstrong B *et al.* (1986) Cohort study of mortality of vermiculite miners exposed to tremolite. Br J Ind Med; 43: 436–44.
Meeker GP, Bern AM, Brownfield IK *et al.* (2003) The composition and morphology of amphiboles from the Rainy Creek Complex, near Libby, Montana. Am Mineral; 88: 1955–69.
National Cancer Institute (NCI). (2005) Malignant mesothelioma: (PDQ) treatment, health professional version. Available at http://www.cancer.gov/cancertopics/pdq/treatment/malignantmesothelioma/HealthProfessional.
National Institute for Occupational Safety and Health (NIOSH). (1994) Asbestos and other fibers by PCM—method 7400. NIOSH manual of analytical methods. 4th edn. Available at http://www.cdc.gov/niosh/nmam.
Pardee JT, Larsen ES. (1929) Deposits of vermiculite and other minerals in the Rainy Creek District, near Libby, Montana. USGS Bull; 805: 17–28.
Peipins LA. (2003) Radiographic abnormalities and exposure to asbestos-contaminated vermiculite in the community of Libby, Montana, USA. Environ Health Perspect; 111: 1753–9.
United States Environmental Protection Agency (USEPA). (1987) 40 CFR part 763. Fed Regist; 52: 41826–905.
United States Environmental Protection Agency (USEPA). (2007) Region 8—Libby asbestos, background on the Libby asbestos site. Available at http://www.epa.gov/region8/superfund/libby/background.
Ward T, Spear T, Hart J *et al.* (2006) Trees as reservoirs for amphibole fibers in Libby, Montana. Sci Total Environ; 367: 460–5.